FACTORS AFFECTING

DIMENSIONAL STABILITY OF WEFT KNITTED FABRICS

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I. INTRODUCTION

Consumer interest in apparel items made from knitted fabrics has increased at a rapid pace during the past few years.

Development of knitting machines that permit high production rate and which allow for textured effects has been partially responsible for this newly re-awakened interest in knitted outwear.

Standard-Coosa-Thatcher,a leading producer of mercerized cotton yarns used for knitted constructions visualized an increasing market for their products in this area and became interested in developing mercerized yarns and technology of knitting processes that would yield a knitted product having greater dimensional stability in use than was now possible with existing products.

A research agreement was entered into with the subject corporation for the School of Textile Engineering of the Georgia Institute of Technology to make a study to more precisely define the problem and to develop improved methods for processing the yarn for knitting, and to devise innovations in existing technologies for converting the yarns into a knitted product.

The project emerged from the conference stage in December of 1964 when Messrs McCarty, Lathem and Flege representing Georgia Institute of Technology met with Mr. C. H. Eagar of Standard-Coosa-Thatcher at Wamsutta Knitting Mills in Morganton, North Carolina to observe the operation of modern knitting machines engaged in making those types of knitted outerwear that had been of greatest concern with reference to dimensional stability. The fabrics may be referred to as double knit construction.

In early January of 1965 a conference was held in Chattanooga with representatives from Tech and Standard-Coosa-Thatcher for the purpose of developing a program for research and to more precisely define the field of greatest interest for study.

A program was developed. Work began on the problem of acquisition of yarn and fabric specimens to be used in the study.

The knitting facility at Georgia Tech was reactivated in part and selected knitting machines were set aside for use in the initial experiments.

Research got under way in late March and has moved forward at an increasingly rapid pace since that time.

This report covers the preliminary work done on the project to date and presents the program proposed for completion of the work originally contemplated as well as that envisioned for continuing the study beyond the original horizon.

II. SUMMARY

A program to determine the shrinkage characteristics, on washing, of the yarn items to be used in the knitting experiments disclosed that yarn shrinkage was of a low order of magnitude as compared with lengthwise shrinkage of fabric ribs knitted from the companion yarn items. Mercerized natural yarns exhibited the lowest shrinkage of all yarn items covered in the test.

Shrinkage of yarn specimens exceeded 1.0 percent for only one or two yarn items from a series of nine items of 24/2; 18/1 and 36/2 count yarns. Fabric ribs knitted from those items shrank more than ten percent for all items where tension on the yarn fed to the machine was zero and the doff force for the fabric was the minimum permitted by the knitting machine. Yarn tension for knitting never exceeded ten percent of the tensile strength of the yarn. Doff force for the knitted rib never exceeded ten percent of the breaking strength of the yarn end assigned to each needle.

All ribs were knitted on a circular hosiery ribber. Some ribs were made from a single strand yarns while others were made from double or triple strands for the single feed station.

The fabric shrinkage patterns prevailed for all of the knitted ribs. Credence is thereby lent to the concept that fabric shrinkage is not directly related to yarn properties as determined by conventional testing methods. Instead, rib shrinkage phenomena may be more directly related to yarn and fiber geometry and their geometric arrangement in the rib, which is significantly influenced by the mechanical characteristics of the machine and the dynamic forces that are created in the rib during the stitch forming process. The geometric characteristics of the stitch appear to change during the chemical and mechanical action that occurs in washing.

Comprehensive tests were made to determine the physical properties of strength and elongation for the yarns used and the variability of specimens within a yarn item. These data were required to permit correlation of differences in rib characteristics with differences in yarn properties if rib characteristics could be explained in terms of yarn properties. Variability in strength and elongation of all yarn items was of a low order of magnitudes. Quality had been well controlled in the yarn manufacturing process.

III. RESULTS AND DISCUSSION

A. Yarn Items and Their Physical Properties

On January 19, 1965 following a conference held in Chattanooga, a program was developed which defined the yarn items that were to be considered in the experimental work to be done on determining the causes of shrinkage in knitted fabrics. There were five items of 24/2 yarn representing both mercerized and unmercerized as well as dyed or bleached items, two items of 18/1 unmercerized and bleached yarn and two items of 36/2 representing a mercerized natural and unmercerized natural yarn. These were the principal yarns that had been used in knitting operations where the knitted products had been reported to Standard-Coosa-Thatcher as having excessive shrinkage.

Before beginning any experimental work on knitting it was thought advisable to run a series of tests on these sample or specimen yarns to determine the differences if any that existed in the yarn properties, both in cones within the same item or from yarns of the same count but representing different processing techniques as mercerizing, dyeing, and bleaching.

1. Equipment Used For Yarn Evaluation

There was available at Georgia Tech a Uster Single Strand yarn testing instrument which was so automated that a large number of tests could be run quite rapidly and inexpensively.

For each yarn item represented, twenty tests were run from each cone of yarn giving a total of 160 breaks or tests for each yarn item. This instrument was also capable of recording the elongation at the break and so these data were also obtained for 160 individual specimens for each yarn item. An item represents a yarn description and/or process for its production. Elongation characteristics were held important.

Another machine which was available for use was an Instron Tester. Five of the cones from each item were run on the Instron. Thus, a total of five specimens from each item were used to describe the properties of the yarn. One reason why the tests was limited to five was because there appeared to be no significant difference from one specimen of yarn to another. The breaking and elongation at break data had already been obtained on a simpler and more automated machine so the data obtained from the Instron were used primarily for the purpose of defining the rate of elongation as a function of the load or force applied. The Instron was therefore capable of illustrating if the rate of elongation was constant throughout the period during which force was applied. In all cases it was noted that the rate of elongation was essentially constant and was a linear function of the force. It was thought that there may have been circumstances existing during the knitting operation where the elongation of the yarn during the knitting process would fluctuate or vary with the rate at which tension was applied to the yarn. The consistency of the results obtained on the Instron illustrated that the yarn was most uniform with reference to elongation rate.

2. Data and Results From Yarn Study

The data obtained in the tests on the Single Strand Uster are given in Table 1. In this table the first five items represent 24/2 yarns. It is to be noted that the mean breaking strength for the 24/2 items ranges from a low 778 grams for the unmercerized natural to a maximum of 1,048 grams for the mercerized and dyed items. The mercerized natural yarn as illustrated by item five had a 1040 gram breaking strength and thus it did not essentially differ in strength from item two. Items five and seven differ only in the sense that one item was mercerized and the other was not. The mercerized item was approximately 50% stronger than the unmercerized item and was therefore theoretically capable of being processed in the knitting machine at a much higher feed yarn tension and a much higher take-off force for the knitted fabric. This observation might lead one to believe that fabrics made from mercerized yarn would show a much higher shrinkage than fabrics made from unmercerized yarn because they could perhaps be knitted under a much higher yarn tension and fabric doff force. The elongation at the break of the unmercerized item seven was considerably higher than the elongation at the break throughout the comparable but mercerized yarn. These data would suggest that the unmercerized item was capable of being elongated to a much greater extent in the knitting operation than was the mercerized item. This probably did not occur because tension and force used industrially in knitting item seven were most probably considerably less than those used in knitting item five. The coefficient of variation for items five and seven did not seem to differ significantly. The coefficient of variation at a value of 5.0% would indicate that all individual breaks within the 160 breaks, for the item, would fall within a range defined by the average of plus or minus 15% of that average and that one third of all of the yarn would have an average breaking strength defined by the average plus or minus 5% of that average. The coefficient of variation is simply the standard deviation divided by the breaking strength for the item and is a convenient means for reporting standard deviation in terms of per cent of the mean value.

The strength variation in the 18 singles and in the 36 two ply was considerably higher than that for the 24's two ply.

Data and experience in processing yarns would indicate that as the count of the yarn declined then the yarn diameter became greater and the forces and tensions that were used in knitting process would increase. The geometric properties of the yarns also change with decreasing count or increasing yarn size. Force required to bend the yarn around the needles increases and much greater forces are required to form the loops or elasticas in the stitches on the knitting machine. Properties of yarns not defined by strength and elongation at the break are of great if not controlling importance in knitting operations.

The unmercerized yarns are much softer than the mercerized yarns and accordingly may be bent to the sharp angles that were observed when the knitting was carried out at a high fabric doff force.

The extent to which drafting or fiber slippage would occur in the yarn as a result the force of application would probably be much greater for the unmercerized items than it would be for the mercerized items where the forces that hold or bond the individual fibers together would be much greater. Inter fiber slippage could act to relieve stresses built up in the knitted fabrics and thereby reduce potential shrinkage. Creep in mercerized yarns under stress is probably considerably less than it is for non mercerized natural yarn.

It is well known that force required to bend mercerized yarns is considerably greater than that required to bend unmercerized yarns.

Since the raw data from which these results were developed are quite voluminous they are not presented as part of this report. They were however used to illustrate the deviation from cone to cone and to prevent usage of any one specimen in knitting that deviated significantly from the mean value. Despite the fact that all cones in any item are essentially identical when the knitting operations are carried out, the specific cones from the items that were used are identified so that the basic reference data for any one particular cone in any item may be used as the reference base when the knitted products from different cones within an item are compared.

TABLE 1

PROPERTIES OF YARN FOR KNITTING STUDY
STRENGTH AND ELONGATION

Item	Count	Break Strength (Grams)	Standard Deviation (Grams)	Coefficient of Variation	Elongation (Percent)
7	24/2	778.5	41	4.30	8.25
5	24/2	1039.5	52	4.98	6.55
9	24/2	964.5	58	5.99	9.1
4	24/2	965.3	55	5.67	7.46
2	24/2	1048.5	65	6.22	6.95
1	18/1	475.5	33	6.99	8.05
3	18/1	498.0	39	7.83	7.05
8	36/2	653.0	42	6.51	7.65
6	36/2	776.0	55	7.15	6.8

B. Yarn Properties - Shrinkage on Washing

Before initiating a study of the dimensional stability of fabrics knitted from Standard-Coosa-Thatcher yarns it was deemed necessary to determine the decrease in length of the yarn specimens on washing, that were to be used for knitting the fabric.

A standard method for determining shrinkage of yarn on washing was not available. A method for determining shrinkage of cotton and linen cloth as defined in Federal Specifications CCC-T-191b - Method 550 was used with modifications. This method was applicable only with respect to equipment, formulation and general procedure. Further, this method is used for evaluation of shrinkage of the knitted items. It was considered desirable to use a common method for evaluating shrinkage of yarn and fabric.

1. Preparation Of Yarn Specimens For Shrinkage Testing

Yarns were received on cones. Nine yarn items with eight different specimen or cones per item were available. A cone identified as 1-8 would represent the eighth cone for Item 1. (18/1 cp. unmercerized dyed light blue).

One skein (120 yards) of yarn was unwound from one cone in each item on to a hand reel at negligible tension. The skein was then placed in a fabric envelope as illustrated in Figure 1.* The purpose of enclosing the skein in an envelope was to minimize yarn entanglement during the washing process and to permit rewinding with a minimum of tension and elongation. Preparation of the yarn specimens in this manner permitted the use of washing procedure as stated in Specifications CCC-T-191b.

Following washing, the yarn - fabric sandwiches were tumbler dried in a manner to be used for the washed fabric. The sandwich was disassembled and the skein placed on a yarn reel from which it was rewound at the negligible tension on the hand reel used for preparing the original skein specimens for washing.

*See Page 20

This procedure permitted accurate measurement of the length of a yarn specimen before and after washing.

Reduction in length of each specimen in the original set of specimens representing each item was of such a low order of magnitude that the test was repeated by a different operator. Data obtained in this series confirmed those of the original test. The test was again repeated with the exception that in this case the washing solution was made strongly alkaline (1.0% sodium hydroxide). For this set, the data obtained closely approximated those obtained in the first two sets. Shrinkage testing of yarn was discontinued after three or more specimens from each item had been covered.

2. Results of Shrinkage Tests on Yarn

Table 2 presents the average of the values obtained for all specimens in each yarn item tested.

These data strongly suggest or demonstrate, without reservation, that shrinkage of yarns could not possibly account for the large dimensional changes noted in knitted fabrics that occurred as a result of washing.

Of further significance is the fact that unmercerized yarns showed higher shrinkage than the mercerized yarns. Commercially knitted fabrics from mercerized yarns had been reported to shrink more than those fabrics knitted from unmercerized yarns.

Although these results do not disclose the causes of, or reasons for, lack of dimensional stability in ingrain knitted fabrics they do suggest that differences in stability of knitted fabrics are not directly related to shrinkage phenomena in the yarns used for knitting. Shrinkage of knitted fabrics is related to mechanical properties of yarns and the forces to which they are subjected in the knitting operations.

3. Variables Encountered In Knitting Operations

Factors which could affect the geometry of the knitted fabric and its dimensional stability may be stated as follows:

1. Specifications for and properties of the yarn
2. Gauge of knitting machine
3. Kinematic principles embodied in the machine design.
4. Tension on yarn as delivered to the knitting needles
5. Force applied to the fabric to remove completed stitches from the needles.

Properties and performance characteristics of knitted fabric must bear some relation to and be influenced by some specific combination of the variables enumerated above, as well as other variables not now understood or specifically definable. Properties of the knitted fabric are defined by the combination of the above variables that is used in the knitting process.

For purposes of the experiments covered by this report some variables associated with some yarn properties and machine characteristics were held constant while a comparative study was made to determine response of the yarn to the process organization in use. Properties of the resulting fabric were then studied.

Some preliminary experiments were made where a fabric was knitted from each yarn item under a prescribed or common set of conditions. A comparative study of these knitted items was made. In presenting the data the conditions for and results of each experiment are described by experiment number.

Experiment 1

Machine Used - 3 1/2" weft knit - 176 needle - Fidelity Machine Company Universal hosiery ribber

Gauge - $\frac{176}{3.5} \Big| 1.5$ = 24 (Wales per inch = 16 as knitted)

Machine operations required that the feed yarn be under tension and that a continous and constant force be applied to doff the yarn from the needles during the knitting cycle.

There is a limiting yarn tension and a limiting doffing force that can be applied. Excessive tension or force will result in broken yarns and/or runs in the fabric.

TABLE 2

SHRINKAGE OF YARNS ON WASHING

	24/2	Yarns			
Item	7	5	9	4	2
Description	Not Merc. Natural	Merc. Natural	Skein Merc.	Merc. Bleach	Merc. Navy
Shrinkage Per cent	1.07	0.28	0.43	0.10	0.25

	18/1	Yarns	36/2	Yarns
Item	1	3	8	6
Description	Not Merc. Dyed Light Blue	Not Merc. Bleached	Not Merc. Natural	Merc. Natural
Shrinkage Per cent	0.53	0.31	1.5	0.41

In this experiment the force was that which would permit a woven fabric that had no runs and could be knitted without a machine stop. Force approximated ten pounds or 25.0 grams per stitch.

Weft or yarn tension was 10 grams in Part A of the experiment and 25 grams in Part B of the experiment. This 25 gram tension on the yarn was of such a low magnitude that very little strain (less than 1.0%) would result. For all practical purposes potential shrinkage of yarn as it was fed to the needle or stitch forming assembly was zero.

5. Results of Experiment 1

Data obtained are presented in Table 3. They are significant only in the sense that fabric shrinkage was of a high order of magnitude. It appears that shrinkage of the fabric was unrelated to shrinkage of the yarn and that the knitting process was responsible for the high fabric shrinkage in this experiment.

Measurement of length or width of a knitted rib leaves much to be desired. In this set of data all measurements were made with the fabric relaxed. Marks placed on the fabric were distorted as a result of tension applied to smooth out the fabric to permit measurement. No statistical significance should be attached to the differences in shrinkage of those items knitted with different tension on the yarns. Fabric items were approximately twelve inches in length. Measurements were probably accurate to 0.25 inches.

Since the yarns were of different counts stress on some yarns was greater than others. Yarn tension was constant for all counts. If yarn tension were a large factor then shrinkage of the fabrics from the 18/1 and 36/2 yarns should have been greater than that noted for the 24/2 yarns. These results suggest that the force applied in doffing the fabric from the needles was the principal variable responsible for the high fabric shrinkage noted for all fabric items, and that yarn stress variation in the range covered was of little or no consequence. Stitch geometry is a function of tension and force.

Experiment 2

This experiment was designed in an attempt to evaluate the relative importance of yarn tension and fabric doff force as factors in causing dimensional changes in the knitted fabrics. The machine used in experiment 1 was also used in this experiment. The gauge of this machine was considered too coarse for knitting single yarns.

It was decided to knit a dense fabric from coarse yarns in order to maximize the frictional drag of the stitch loop over the yarn during the knitting process when the existing stitch on the receding needle was doffed to form the new loop, and to keep the stitch length at a low value and the courses at a higher value.

For plain knitted fabrics it is generally accepted that the stitch length is defined by the following equation:

$$1 = 2\ C + W + 5.94\ d$$

1 = stitch length - C = number of courses per inch
W = number of wales per inch
d = yarn diameter in inches

All of the variables in the above equation must dimensionally consistent.

Yarn items as follows were used in this experiment:

18/1 unmercerized bleached - 3 ply - equivalent to 6 ply of 18/1

24/2 mercerized bleached - 2 ply - equivalent to 4 ply of 24/2

For each item the equivalent cotton count of the yarn being knitted was six. The yarns were not twisted hence knitting was done from three individual cones in the case of items three and from two cones in the case of item four.

Conditions prevailing in the test were as follows:

Conditions	A	B	C	D
grams - Tension	0	0	80	80
pounds - force	11	20	11	20

Data obtained in this experiment are shown in Table 4. Shrinkage in the fabric as a function of tension and force are shown.

Dimensional instability of the fabric as knitted makes it difficult to measure accurately the length of the test specimens before and after washing.

The data suggest only that the shrinkage of the knitted items was quite high. Since only one piece of fabric was knitted and washed the data are statistically inadequate for determining the effects of the range of tensions and forces covered in the experiment. Shrinkages were of the same order of magnitude as those noted for experiment 1

TABLE 4

SHRINKAGE OF KNITTED FABRICS
EFFECT OF YARN TENSION AND DOFFING FORCE

Descrip.	Code	Yarn Tension	Doff. Force	Shrinkage % S_1	S_2
(18/1) 3 ply	3-8	0	11	25	16
	3-5	0	20	24	21
	3-1	80	11	9	7
	3-4	80	20	23	14
(24/2) 2 ply	4-7	0	11	25	16
	4-6	0	20	22	15
	4-2	80	11	18	10
	4-3	80	20	37	11

Yarn tension in grams - Doff force in pounds

S_1 = Shrinkage of fabric on washing where all measurements were on fabric in the relaxed state.

S_2 = Shrinkage of fabric on washing where all measurements were made on the rib on the 3 1/2" diameter cylinder.

For determining the values of shrinkage S_1 in Table 4, the knitted pieces were laid out on a smooth surface without tension and marks were made in the pieces for an approximate one footh length of test specimen. Identification marks had been placed in the fabric with a sewing machine. Following washing and drying the same method for measurement was used as described for experiment 1.

$$S_1\ (\%) = \frac{\text{original slack length} - \text{washed slack length}}{\text{original slack length}} \,\Big|\, 100$$

Although the diameter of the tube as knitted was 3.5 inches and its circumference as knitted was 3.5 or 11.0 inches the actual slack circumference as doffed from the machine was only 6.0 inches. Thus wide short stitches as knitted were transformed into long narrow stitches, as a result of the force applied to doff the fabric from the needles. On washing and relaxing the geometric structure of the stitches changed. Stitches became shorter and assumed the shape of an elastica ( ). Shrinkage or dimensional change occurred therefore as a result of a change in stitch shape or structural geometry of the fabric and was unrelated to the shrinkage characteristics of the yarn. Shrinkage of knitted fabrics as doffed from the knitting machine is more closely related to yarn and fabric geometry than to yarn properties.

Shrinkage of yarn as delivered to the knitter may not be nearly as important as the potential shrinkage introduced in the yarn as a result of the tension applied in knitting and the force applied to the fabric during the knitting process. Dynamic forces may be of greater consequence than static forces.

For determining the values of S_2 tubes as knitted were pulled over a brass cylinder having a diameter of 3.5 inches. Length of the tube on the cylinder ranged from 75 to 80 per cent of the length as doffed from the machine. Stitch shape was now in the form indicated.( ).

Following measurement after washing, and drying, the tubes were again pulled over the cylinder and distance between the dimensional marks noted.

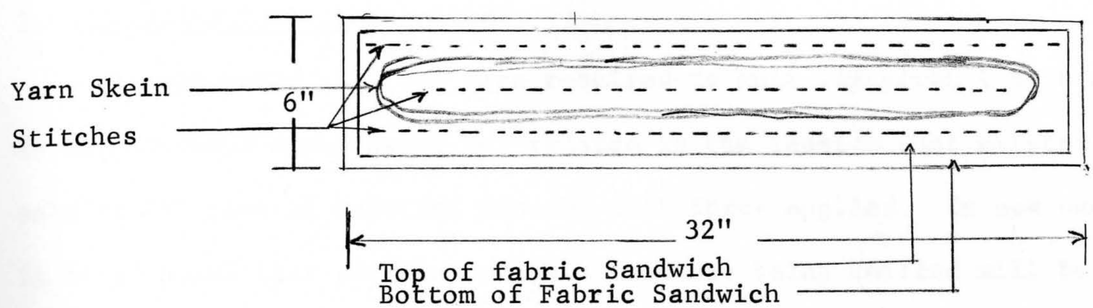
$$S_2\ (\%) = \frac{\text{original length on cylinder - washed length or cylinder}}{\text{original length on cylinder}} \Bigg| \ 100$$

Before measurement, the tubes were smoothed out on the cylinder, placed under mild tension and permitted to relax.

This experiment illustrated that shrinkage results were greatly affected by a number of variables and that improved experimental methods and control techniques should be incorporated in future experiments both with reference to knitting technique and shrinkage measurement. All measurements should be made under controlled fabric diameters for the knitted tube during measurement of the length of the tube under controlled tension. This idea will be further discussed under experimental program proposed.

FIGURE 1

FABRIC SANDWICH FOR YARN SHRINKAGE TESTS



C. Proposed Program for Future Work

1. Introduction

Analysis of the preliminary data obtained in the experiments described in the body of this report indicates that an approach to a new experimental program should be developed, which is more sophisticated than the one that has been followed in the past experiments.

2. Variables to be Controlled

It was noted that the yarn required to knit any given length of fabric in the previous experiments was related to the tension that existed on the yarn at the time of knitting and the doff force applied. In new experiments it is proposed that packages of yarn that are being knitted will be weighed on an appropriate balance so that the quantity of yarn required to knit any given length of fabric or any number of courses can be accurately determined. At the same time it is proposed that the yarn being knitted will pass through a tensiometer so that the tension on the yarn can be accurately measured throughout the knitting process. In addition it is proposed that the knitting operations will be continuous from beginning to end of the experiment so that there will be no time lags and no stops during the knitting of any one sample which might result in the elongation of the rib while it was in the knitting frame. Further, the yarn as it is being knitted will be passed over a measuring device so that the total yardage of yarn going into the rib may also be measured. The variable to be controlled or determined here is simply that of finding out if there is any stretch out of the yarn or elongation of yarn between the measuring device and the servo device for the knitting needles. As an example, it is entirely possible that the sudden jerk of the needle as it pulls the yarn down into the slot may cause an enlongation not measurable by the static measuring devices. The use of a dynamic tension measuring device is indicated and will be acquired.

It will be possible to control or measure the take-off force that exists on the rib and accordingly this will be measured so that the relationship that exists between the yarn weight, yarn length, and length of fabric or the number of courses required to knit any given length can be accurately determined.

It is desirable to have a reference tube as knitted without having ever been washed or processed, for purposes of comparing the original knitted fabric with the material after it had been washed and dried.

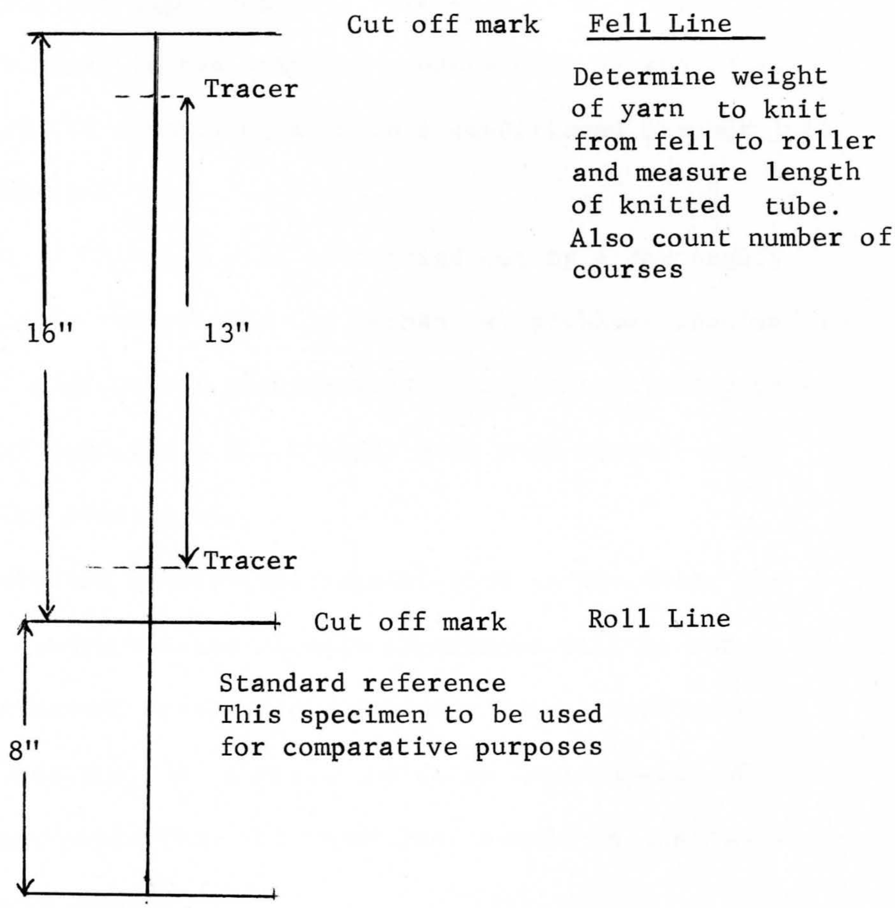
This can be done by following a routine or procedure as illustrated in figure 2 which is shown below. The general scheme will be to get the sample under way in the knitting machine and to knit approximately eight inches of the rib and then to place in the rib a tracer yarn and to measure the weight and yardage of yarn that will be required to advance the tracer mark from the fell of the knitting machine to the take-off rolls. An additional length of tubing will be knitted and then another tracer placed so that the ends of the ribs may be appropriately sealed; with some plastic material to prevent ravelling during the washing process and to provide a base or means for supporting a weight on the fabric so that the tension on the tube can be controlled while the measurements are being made prior to the washing operation and following the washing operation.

All measurements will be made under controlled tension. This will permit a comparison of wales per inch and courses per inch on the knitted tubes under a controlled range of wale wise tension that may exist in the tube during the experimental program.

It is further planned to take both the original and the washed samples and to pull them over a transparent tube before and after washing where it may be possible to make photographs to determine the shape or the geometric pattern of stitches.and how the geometric pattern had changed as a result of the washing process.

FIGURE 2

PLAN FOR KNITTED SPECIMENS



1. Measure length as knitted
2. Measure length as doffed and after placing on flat platen or circular tube.
3. Wash specimen and place on platen for measurement
4. Calculate shrinkage
5. Photograph stitch for original and washed specimen.

It is hoped that it will be possible to put a counter on the machine so that a record may be made of the number of courses actually knitted per inch of travel of the knitted tube as it moves downward from the fell to the take-off rollers.

The room in which the knitting is to be done will be conditioned during the knitting operation. It is not possible to keep this knitting room under controlled conditions during the night and over week ends. So, accordingly the packages that are to be used in the knitting process will be stored in a conditioned room and carried to a knitting room in a conditioned chamber just prior to the knitting operation.

The entire operation of knitting will be carried out by a thoroughly competent technician who fully understands the mechanical problems involved in knitting and who will make appropriate observations during the knitting process and record any unusual conditions which might have some significant effect on the outcome of the experiment.

In order to lend increased statistical significance to the data, replicates, triplicates, or quadruplicates of each experiment will be run in order to assure that the observed result did not result from a random, or chance, or uncontrolled condition. If a result or datum is incapable of being repeated on successive experiments than the experiment should be discounted as being of probable significant value.

Experiments will be run using single strand yarns and then followed up with experiments using two, or three or more plies of the yarn as received. This will result in fabrics of increasing density and will greatly increase the strain on the yarn during the knitting process as the number of plies used in the knitting is being increased.

3. Knitting on Other Machines

A knitting machine is available which was designed primarily for knitting of men's hosiery.This machine has been reworked and is now capable of knitting a continuous rib. In this machine no force is required to doff the knitted fabric from the needle. On this machine only the tension of the yarn as it is fed to the needles may be controlled. The knitted tube is doffed from the machine by specially designed doffing plates.

It will be possible to compare fabric shrinkage data on ribs from this machine with those products produced on a different knitting machine where considerable force is supplied to the rib as it is being doffed.

On this machine a record will also be made of the mass of yarn used in the knitting process and the yardage of yarn used in the knitting process per inch of fabric knitted.

Proposed New Machines

Although a fifteen inch cylinder and dial machine capable of making a double knit fabric is available it is not yet in working order. It is hoped that this machine will be reworked to a point where it may be employed for making a simple double knit fabric which is within the capabilities of the machine. The present opinion is that with this machine it will be possible only to make a simple interlock fabric. It is believed that this simple interlocked fabric will be adequate for our needs in this experiment. It is not expected that this machine will in any way be capable of duplicating the total performance of the Morat machine that seems at this time to be the leading machine for use in manufacturing or knitting any particular style or type of double knit fabric that is in use by the trade. The Morat is capable of knitting a wide range of constructions. When the time comes to activate this machine and put it in use additional quantities of yarn will of course be required. In the meantime it may have been possible to acquire commercially double knit fabrics for which some reference or production data may be obtainable. It may be far simplier and less time consuming to start this program with random samples of commercial double knit fabrics and make studies of shrinkage of those fabrics under varied conditions of washing, than to acquire a new machine.

From a long range point of view however, acquisition of a modern up to date knitting machine is indicated and steps toward acquisition of a Morat machine have been taken.

APPENDIX I

KNITTING PROBLEMS ASSOCIATED WITH MERCERIZATION

A conference was held in Chattanooga,Tuesday, January 19th with the following people present: Richard Thatcher, Marshall Goree, Charles Eagar, Elroy Rollins, Ed Norman, and David Smith. (*)

The meeting opened with discussions centered around an attempt to define in an unambiguous manner the problem that was to be resolved.

1. Historical

When an effort was made to introduce Durene yarns for ingrain knit products problems arose with dimensional stability of the products as doffed from the machine. These products were knitted from mercerized and/or bleached and dyed yarns. No finishing processes had been used. Customers suggested that the yarn shrank too much and proposed that the yarns could possibly be sanforized.

Mercerized dyed yarns 20/2 - 36/2 that were being considered for use in outer wear fabrics did not permit products, as doffed from the machine ready for the cutting table. It would be highly desirable to provide for knitters, a Durene yarn having properties which would permit products as knitted, to be used for garments without having to go through finishing processes.

2. Effect of Finishing Processes

Fabrics from 36/2 mercerized yarns yielded products that were considered satisfactory when the knitted products were pre set or appropriately finished prior to being cut and sewed into garments.

The inference to be drawn here is that Durene yarns will yield satisfactory products when finishing processes are applied to the knitted piece goods. Chemicals applied for dimensional stabilization are particularly beneficial.

(*) Messrs Taylor, Hyden, McCarty and Flege representing Georgia Tech.

3. Effect of Dyeing Process on Yarn Performance

Experience gained with products knitted from Durene, as mercerized, did not differ from that reported for Durene yarns which had been dyed. An unmercerized or undyed yarn would not be used in a garment without having been finished.

4. Experience with Single Yarns

Dimensional stability problems were not encountered with products knitted for 20/1 yarns ($0.68 per lb.). Singles yarns were not mercerized. No data were available for items made under comparable production techniques for 40/2 Durene yarns ($1.22 per lb.).

No trouble was reported for 20/1 mercerized yarn from combed peeler cotton. It would be interesting to note if the knitted items were finished following knitting. It is difficult to understand why 2 ply yarns should behave differently from 20/1 yarns where all other operating conditions were identical.

Some properly designed controlled experiments on response of yarns of varying history to the same knitting techniques might shed more light on the causes of reported troubles assigned to the yarn or process.

Processes may be designed that are suitable for any yarn, or yarns may be developed that respond satisfactorily to any specific process.

Some items knitted from 12/1 combed yarns dyed pink were quite satisfactory as compared with the same or similar product from 24/2 Durene.

Export Durene, as well as other export yarns, were being knitted and cut as knit without benefit of finishing processes.

5. Standard-Coosa-Thatcher Process

For the chain warp mercerizing process 50 warps of 50/2-378 ends were being mercerized. Two mercerizing ranges were being operated. The ranges made use of two distinctly different types of drying ranges.

Yarns were coiled down in receivers - 378 ends per receiver - as doffed from the dryers. Yarns were then quilled and later wound on cones.

The quilling operation was carried out under conditions where a high stress was placed on the yarns being quilled.

It would be of interest to determine the shrinkage characteristics of garments knitted from a slack dyed and quilled yarn. If maximum tension were placed on the yarn during knitting, cold drawing could occur at the knitting machine.

If mercerized yarns were cold drawn or quilled at maximum tension prior to delivery to the knitters then the shrinkage characteristics of the knitted items might be relatively insensitive to the tension applied to the yarns in knitting. All yarns were dyed following mercerization. Yarns to be bleached were wet out, bleached cold with sodium hypochlorite and bleached with peroxide in a conventional manner. Approximately 40,000 pounds of yarn per week of a 200,00 pound production equivalent to 20% of total production were being bleached in the continuous bleaching range. These 40,000 pounds represented yarn to be sold as white.

6. Cottons Used

30/2 and lower count yarns were being spun from Delta 1 3/32 bright middling cotton. For some 30/2 and 32/2 a blend of 75% California and 25% Delta cotton was used. For the 36/2 - 60/2 range, California cotton was almost if not exclusively used. 70/2 and 80/2 were produced from 1 1/4" - 1 3/16" El Paso area cotton. These were most probably Pima cottons equivalent to Sea Island or Egyptian cotton. Pima is an exceptionally strong fine cotton.

7. Proposed Program - Yarns to be Used

1. 18/1 C.P. Unmercerized dyed Light Blue, wound over disc wax and emulsion.

2. 24/2 C.P. Mercerized dyed Navy, wound over disc wax and emulsion.

3. 18/1 C.P. Unmercerized Bleached, wound over disc wax and conditioned.

4. 24/2 C.P. Mercerized Bleached, wound over liquid wax and conditioned.

5. 24/2 C.P. Mercerized natural, wound over liquid wax and conditioned.

6. 36/2 C.P. Mercerized natural, wound over liquid wax and conditioned.

7. 24/2 C.P. Unmercerized natural, wound over disc wax and conditioned.

8. 36/2 C.P. Unmercerized natural, wound over disc wax and conditioned.

9. 24/2 C.P. Skein Mercerized, wound over liquid wax, not conditioned.